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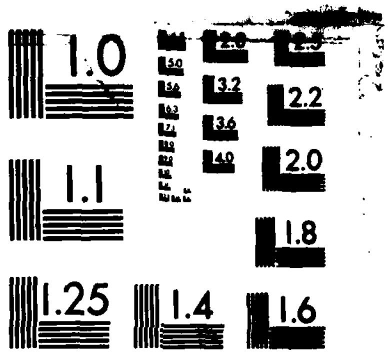

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16. Abstract

FAA-funded Doppler weather radar activities during the period 1 October to 31 December 1984 are reported.

The test-bed Doppler weather radar integration testing continued in Olive Branch, Mississippi after the lightning strike damage was repaired. Preliminary tests indicate that the objective of 50-dB clutter suppression is being obtained in the field and that the system sensitivity is very close to the NEXRAD specification. Installation of an improved lightning protection system neared completion.

The Lincoln mesonet continued to obtain useful data throughout October and November. A strong microburst with peak winds of 68 mph was recorded in the immediate vicinity of Memphis International Airport on 20 October. The mesonet and LLWSAS data from Memphis, and Doppler weather radar data from the National Center for Atmospheric Research JAWS program and the National Severe Storms Laboratory, are being analyzed to develop low-altitude wind shear detection algorithms. Clutter measurements were carried out at Eglin Air Force Base/Ft. Walton Beach Airport, the Memphis Airport, and the Olive Branch, Mississippi test site.

Work continued on the development of weather radar products for the Central Weather Processor. This work focused on tracker refinement studies and NEXRAD-compatible processing of the existing reflectivity-only weather radars.

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WEATHER RADAR STUDIES

I. INTRODUCTION

The principal areas of emphasis for the weather radar program over the period October-December 1984 have been:

(a) Development of a transportable Doppler weather radar test-bed to be utilized in a series of experimental programs during 1984-86.

(b) Reduction of data from the coordinated Doppler weather radar — aircraft experiments in the Boston, Massachusetts area during the summer of 1983.

(c) Planning for the first set of transportable test-bed experiments in the Memphis, Tennessee area.

(d) Development of detailed specifications for certain Central Weather Processor (CWP) products to be generated by the NEXRAD system.

Progress in each of these areas is described in the sections which follow.

II. TEST-BED DEVELOPMENT

The principal objectives for the transportable test-bed have been to develop a NEXRAD-like Doppler radar which can be used for:

(a) Resolving the principal uncertainties in algorithms for detection and display of enroute and terminal hazardous weather regions.

(b) Obtaining feedback from operationally oriented users on the utility of strawman end products for improving safety and efficiency of airspace utilization.

(c) Investigating Doppler weather radar — CWP interface issues.

(d) Providing a data base for FAA specification of NEXRAD, terminal weather radar, and NEXRAD/CWP interfaces.

During the 1984-85 experiments, the transportable test-bed radar will be used in the following modes:

(a) As a terminal Doppler weather radar to detect low-altitude wind shear (LAWS) and other hazards both:

  (1) "On-airport" using 360° PPI scans with principal focus on glide slope headwind/tailwind shear, and

  (2) "Off-airport" using sector PPI scans with occasional RHI scans to focus on microburst/downburst detection in midair stage.

(b) As a NEXRAD "network" sensor with a 5-min. volume scan and principal focus on products of particular interest to the FAA such as turbulence, layered reflectivity, and LAWS.

(c) For "scientific" data acquisition (as in the JAWS Project and NSSL Spring Programs) characterized by scientist-controlled scan patterns based on real-time three-moment displays.

Figure II-1 shows a block diagram of the test-bed.

The test-bed activity during the quarter focused on resuming the integration testing and installation of an improved lightning protection system. Bad weather slowed down the underground lightning protection work and delays were encountered in obtaining an operational backup diesel generator. These difficulties notwithstanding, considerable progress was made in the system integration and checkout. We anticipate commencing useful weather measurements by the end of February.

A. RADOME

The radome continued to operate satisfactorily throughout the period. No deflations occurred and the backup diesel generator did not have to be utilized.

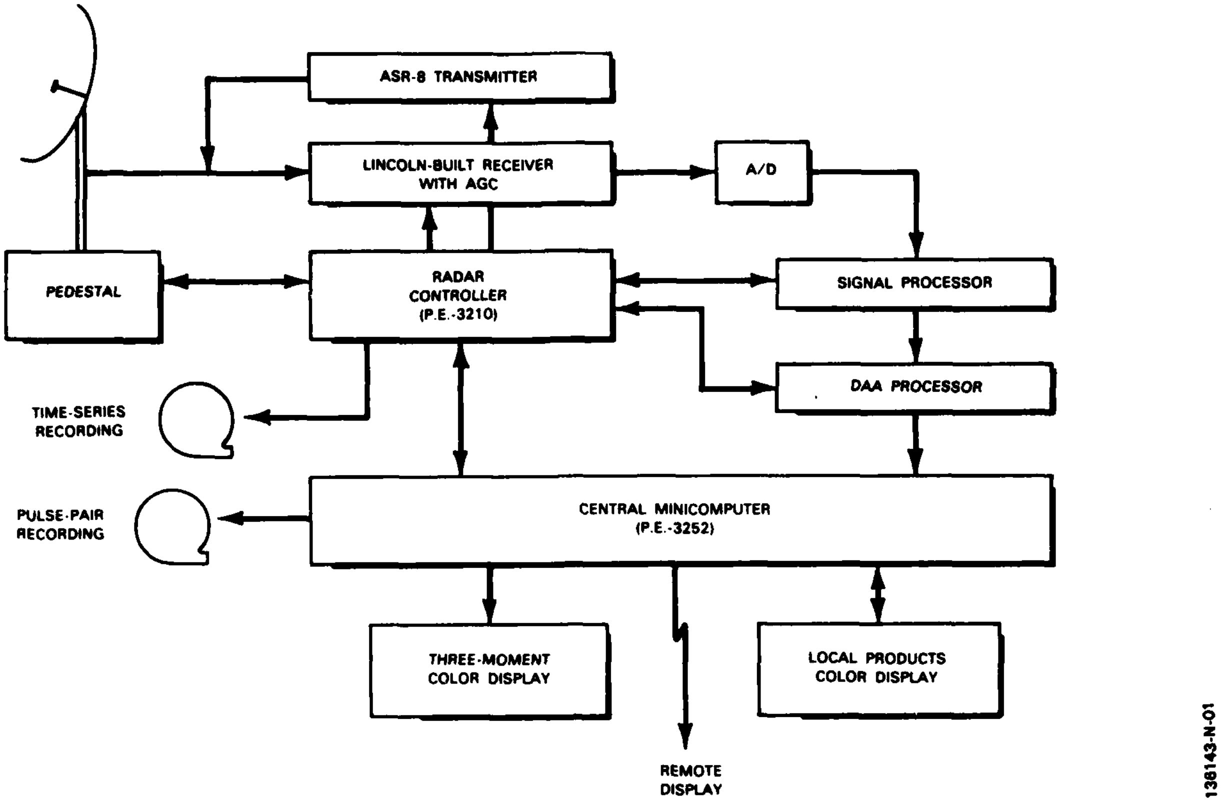

Figure II-1. Test-bed block diagram.

B. ANTENNA

The VSWR was reduced to 1.3 by reducing the bend in the waveguide near the horn and by modifying the feed-horn window. A close inspection of the antenna showed that the nuts which hold the support struts together were loosening. These were replaced with elastic-stop nuts; the structure was then rebalanced.

In the next quarter, we plan to characterize the waveguide and feed-horn losses by making sun measurements.

C. ANTENNA MOUNT

The pedestal control components which were damaged by lightning were repaired at Scientific Atlanta and returned to Olive Branch. A large portion of the servo compensation adjustment procedure had to be repeated after reinstallation. Several circuit changes were effected to increase gain and position responses and digital rate stability.

The pedestal is being reliably and safely maneuvered by the initial control computer program using a combination of rate and position commands. Accelerations of $10°/s^2$ in azimuth and

$14.5°/s^2$ in elevation are achieved. The final control program, to be implemented during the next quarter, will use only rate commands and will achieve the accelerations of $15°/s^2$ and $16°/s^2$ in the two axes respectively, which are obtained under manual control.

D. TRANSMITTER/RECEIVER

It was reported in the last Quarterly Summary that these subassemblies were only slightly damaged by the August lightning strike. Several problems appeared, however, after that writing. Many transistors and diodes in the system control circuitry were discovered to have been damaged over a period of time as various functions were addressed. The RF driver and the receiver front-end amplifier were also damaged. As far as is now known, all repairs have been made. Some elements of the receiver chain were reconfigured to improve the system noise figure and dynamic range.

Using a mixture of measured (where possible) and calculated parameters, a precipitation power budget for the test-bed radar was prepared. Table II-1 is a summary of that budget and shows that the test-bed system should be capable of producing a signal with 0 dB signal-to-noise ratio for a weather echo of –7.6 dBz reflectivity at a range of 50 km. For comparison with NEXRAD, a set of reasonable radar parameters was gleaned from Table 1 of NOAA Technical Memorandum ERL NSSL-86, the final JDOP report (March 1979). The test-bed has a slightly better antenna and slightly greater average transmitter power than the strawman NEXRAD radar. It will be necessary to reduce the test-bed system losses to less than 1 dB in order to realize the required NEXRAD sensitivity of –8 dBz for 0 S/N at 50 km. The design goal for detection capability of the JDOP strawman NEXRAD was 20 dBz for S/N = 3 dB at 250 km. This translates to +3 dBz for S/N = 0 dB at 50 km, so both NEXRAD and the test-bed radar systems are considerably more sensitive than the original performance guideline.

E. SIGNAL PROCESSOR

The test-bed signal processor is a hard-wired computation unit, designed to perform the front-end processing of weather radar data. This processing consists of three basic parts: AGC compensation, clutter filtering, and autocorrelation processing.

The AGC compensation and autocorrelator sections of the processor have been operating properly for the past few months. Noise problems on the interface signals to and from the processor have required some improved shielding of the interface cables, but these problems seem to have been resolved. The signal processor is therefore capable of providing autocorrelation estimates, from unfiltered time series, for overall system testing and operation.

The clutter filter portion of the signal processor is currently being tested and debugged. A number of timing problems have been found, and all but a few have been corrected. The remaining problems cause the filters to work improperly on various range sections, while certain range gates appear to function properly. The remaining problems in the processor should be corrected by the end of January, to give a fully operational "first trip" signal processor. Work on the "second trip" signal recovery and autocorrelation modules, as well as the time series collection buffer, will follow.

TABLE II-1

Precipitation Power Budget for Test-Bed Radar System

Ze (dBz) = Pn (dBm) + Zc (dBz) – pav (dBm) + 20 log (r/r_o) + Losses (dB)	
Pn: kt_o =	–114 dBm/MHz
Bandwidth at I.F. = 1.25 MHz	+1 dB
Receiver Noise Figure = 4 dB	+4 dB
	–109 dBm
Zc: = 10 log $(7.38 \times 10^{27}\ m^{-2}/s)\ \dfrac{Fr_o^2}{f^2G^2\phi\theta}$	
7.38×10^{27}	+278.7 dB
F = 1000 Hz	+30 dB
$r_o^2 = (1000\ m)^2$	+60 dB
$1/f_t^2$ = 2.9 GHz	–189.2 dB
$1/G^2$ G = 46.4 dB	–92.8 dB
$1/\phi = 0.94°$	+17.85 dB
$1/\theta = 0.94°$	+17.85 dB
	+122.4 dBz
Pav: Peak Power = 1.07 MW	+90.3 dBm
Duty Cycle = 0.65/1000	–31.9 dB
	+58.4 dBm
20 log (r/r_o) = 50k/1k for 50 km	+34 dB
Losses: Receiver Mismatch	+1.0 dB*
Waveguide and System	+2.4 dB
	+3.4 dB
Ze (dBz) = –109 + 122.4 –58.4 + 34 + 3.4 =	–7.6 dBz for zero S/N at 50 km
*For Range-Distributed Targets	

B. SUPPORTING SENSORS

1. Mesonet Operations

a. Hardware

All back-ordered Data Collection Platforms (DCPs) were received in Memphis in October, but three of them did not function properly and were sent back to the factory for warranty repair. These were fixed and returned in November. However, three DCPs were damaged by lightning and sent back to the factory for repair. One module (one of three in a DCP) was damaged so badly that it could not be fixed, so a new one was ordered in December. We have now changed our estimate from one spare for every ten DCPs to one for every six to maintain thirty working stations at all times. Thus, two new DCPs were also ordered. Synergetics has found that small gas discharge tubes placed on all I/O lines can successfully protect the electronics from lightning damage. These were also ordered and will be installed as soon as they are received.

We have largely depleted our inventory of spare sensors through the long 1984 data collection period. Rain gauge potentiometers are extremely susceptible to surge damage from nearby lightning strikes. Two wind-speed sensors were found reading low because they were mechanically prevented from turning by broken rubber O-rings. These O-rings will have to be replaced every four months. By the end of December, all of the sensors were inventoried and orders were placed for additional spares. A fix was found for the peak wind-speed "chatter" problem which involves simply replacing a resistor and capacitor in the base of the anemometer.

The mesonet was turned off on 3 December and all the sensors were packed and shipped back to Lincoln. We decided to leave the rain gauges in the field with heavy plastic covering the opening in the top. We also decided to leave all the station hardware including solar panels and batteries in the field. Synergetics has specified a maintenance procedure to be performed on the DCPs after they have been in the field for a year. We will perform this maintenance procedure at our field site so that we will not have to ship the equipment back to Lincoln.

The paperwork has been put through to renew our data downlinking contract with Synergetics for the next 12 months.

Orders were placed during December for the parts to build 9 V voltage regulators to power the barometers. These will allow us to nearly double the resolution of our pressure measurements. During the 1984 data collection, a regulated 5 V source was used for the barometers.

b. Calibration

An RFI was issued to Vaisala, Inc. in Woburn, MA for the job of calibrating all of our temperature-relative humidity probes. Two of us visited Vaisala on 13 November. We found them to be eager and well equipped to do the work. A purchase order was promptly issued upon receipt of their quotation, and then the probes were shipped to them on 31 December. They promise to complete the work, which also includes replacement of all the "humicaps", by the end of January.

Dr. Ryan of Group 76 has again agreed to calibrate our barometers in the Lincoln Space Lab pressure chamber. They will be able to finish the work in one week once the chamber becomes available (mid-January). An excitation voltage of 9 V will be used for the calibration tests to match the voltage we will be using in the field.

A schedule for all of the cleaning, calibration, and testing of the wind sensors to take place in January was developed. The test-bed site manager will arrive on 14 January from Olive Branch to help out with the testing.

2. LLWSAS Recording System

The LLWSAS recording system at Memphis International Airport continues to work satisfactorily. We have not experienced any loss of data since installing a backup power module.

3. University of North Dakota (UND) Radar Operations

Several discussions were held with UND regarding the format for their data tapes from 1984. It was eventually concluded that the best approach would be for UND to convert their tapes to the "universal exchange format" recommended by the American Meteorological Society, as most researchers (including Lincoln) have read packages for data in that format. We expect to receive the converted data tapes in the next quarter.

UND will be modifying their mount in the next quarter so it can be used for sector scan operations. We anticipate their radar arriving in Mississippi in April 1985.

4. Aircraft Support

No detailed arrangements have been made as yet for aircraft support in 1985 although it is anticipated that the UND Citation II jet and the FAATC Convair will both be available.

5. Additional Weather Data

The RRWDS and GOES Laserfax equipment continues to perform without problems. A purchase order for the leased line to connect the DiFax had been issued by the end of the quarter, but the line had not yet been installed.

A design was completed and components were ordered for a recording system to be used in conjunction with the RRWDS weather display equipment. The recorder will permit recording and playback of RRWDS data for up to 48 hours without interruption, using a single reel of tape. This RRWDS recording capability can either

(a) provide complementary surveillance scan data when the test-bed is operating in a TDR (e.g., sector scan or RHI) mode, or

(b) provide complementary adjacent radar coverage for CWP mosaicing studies when the test-bed is operating in a NEXRAD mode.

III. MEMPHIS SITE PLANNING AND SUPPORTING SENSORS

A. SITE SELECTION AND PREPARATION

1. Lincoln Radar Site

The lightning protection system installation was a principal focus of activity at the Lincoln site. The underground counterpoise (Figure III-1) connections were cadwelded and grounding wires were attached to the various structure grounds. The 125-kW engine generator pad was poured; the generator will be delivered in January. Two 70-ft poles with lightning rods were installed beside the radome and the display trailer to further protect against direct lightning strikes.

In the next quarter, the engine generator will receive an FAA modification kit which permits a smooth switchover from the power line to local generator power. When this is accomplished, the generator will be connected to the power line.

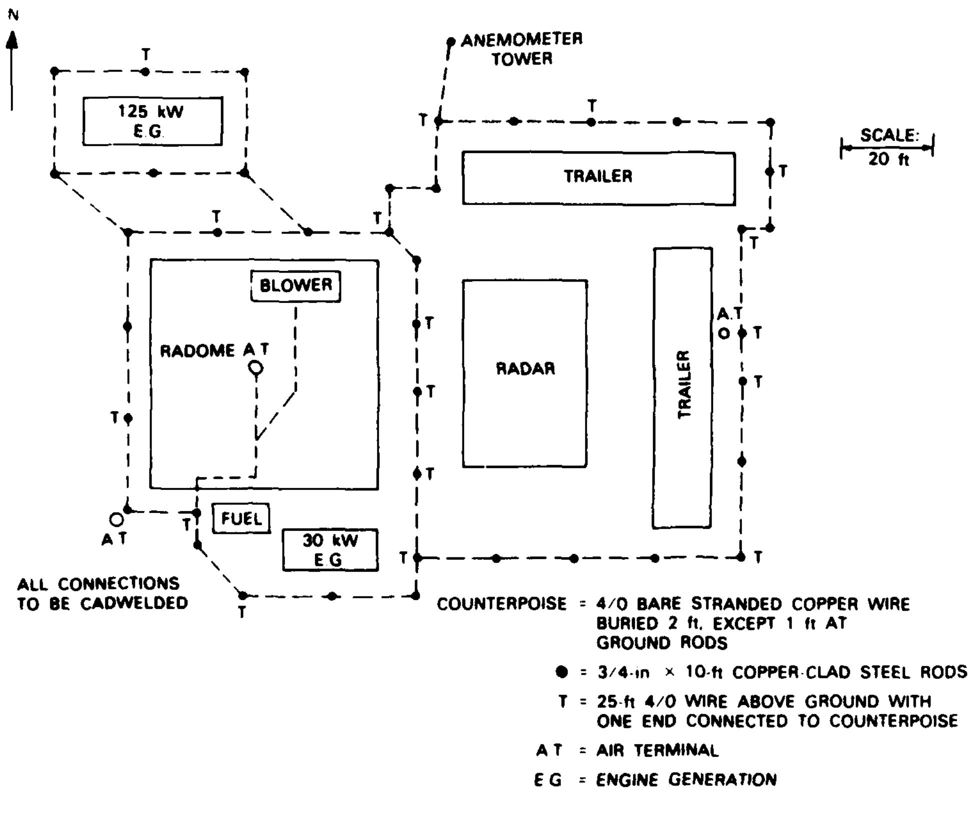

Figure III-1. Grounding counterpoise.

Experimental and analytical studies were made of blocking and scattering by objects on the roof of several new buildings constructed near the site. Scattering measurements made with the moving target simulator at several positions suggest that reflections from the current obstacles are sufficiently weak so as to not cause significant errors in weather interpretation. Calculations suggest that the blockage effects will also be tolerable.

Consequently, we have postponed any plans to increase the antenna phase center and radome heights. Preliminary engineering feasibility studies suggest that a 20-ft height increase can be accomplished if necessary.

2. University of North Dakota (UND) Radar Site

Based on the Lincoln radar site experience, a design for a counterpoise and underground power feed system for the UND site was completed. In the next quarter, this system will be installed as will an FAA-supplied engine generator. UND will install lightning suppressors on their power system and van to radar signal lines similar to those used on the Lincoln system.

3. Mesonet Sites

New 12-month contracts for the mesonet sites and thank-you letters were mailed to all landowners during October. Because legal problems were encountered in obtaining a signed landowner contract for site #27, the station was moved to a new site approximately one mile east of its previous position. The relocated site #27 was vandalized on 29 October. Local police filled out a report, took pictures, and dusted for fingerprints.

The wind sensors, rain gauge, and antenna were destroyed but the DCP, solar panel, and other site components were intact. Better locations in the same approximate area could not be found. Therefore, we have decided to move the station farther into the same field and away from the road. And, if the township permits us, we will fence in the entire site with "hurricane" fencing, install a locking gate, and place barbed wire around the top of the fence (about 6 ft high).

A decision was made to move station #4, which was currently located at the far northeast end of the network, to a site closer to the town of Olive Branch. In December, a site was found and a new landowner agreement was signed and returned to Lincoln for signature. The new location is just west of the town of Olive Branch where we previously had a "gap" in the network.

Also, Ted Fujita has agreed to take panoramic photographs at each LLWSAS site, but he feels we should wait until next June when the leaves are full again. At that time we will need to obtain FAA approval to bring a "cherry-picker" out since the anemometer height is approximately 30 ft AGL. This information will be used to correct the wind-speed data (as a function of azimuth) for site obstructions.

2. Additional Doppler Test-bed

Studies on constructing a second test-bed Doppler weather radar for use in LAWS detection studies near Stapleton, Colorado in 1985 were halted as it appears that funding for such a radar is not available. Prior to halting these studies, we located some suitable naval gunnery mounts which are currently in storage at an Ohio military depot. These mounts have recently been modified and successfully used by other Lincoln programs on Kwajalein Atoll.

Throughout the quarter, as more signal processor hardware was checked out and put on line, the main minicomputer was used to help locate remaining problems in the signal processor; special-purpose diagnostic software in the main minicomputer was written for this purpose.

I. TEST-BED ENHANCEMENTS

1. Automatic Velocity De-aliasing

Reliable automatic de-aliasing of Doppler velocities is essential for the Terminal Doppler Radar (TDR). An attractive approach to this problem is to use staggered pulse repetition time (PRT) sequences. However, it is very difficult to obtain good clutter filter performance with such sequences. In mid-June, a study was initiated to develop techniques for clutter suppression in sequences in which the interpulse spacings alternate from pulse to pulse. The initial focus was on the development of staggered PRT clutter filter design techniques and simulation packages for the evaluation of weather parameter estimate degradation caused by the filters.

The current focus of attention in the automatic velocity de-aliasing studies is the phase characteristics of staggered PRT clutter filters. Phase contamination induced by the staggered PRT filters, left uncorrected, results in unreliable aliased and de-aliased velocity estimates. A table look-up scheme has been developed, with entries into the table being keyed by the spectral width estimate and the contaminated velocity estimates, which reduces estimate errors to an acceptable level for low stagger ratios. As de-aliasing with accurately aliased estimates requires a table look-up, the above mentioned scheme does not constitute an appreciable increase in the computational requirements over that of the usual de-aliasing algorithm.

A second technique, which may prove to be applicable to a wider range of stagger ratios, is being developed for ameliorating phase contamination. It consists of the cascading of staggered PRT IIR (Infinite Impulse Response) phase equalization filters with the FIR (Finite Impulse Response) sections of the staggered PRT filters.

A sampling theorem for staggered PRT sequences was generated. The theorem indicates that although a staggered PRT sampling scheme does increase the effective Nyquist Interval, the spectrum of the staggered sampled sequence may be considerably more complex than that of the same signal sampled in an equispaced fashion, at the PRT directly corresponding to the effective Nyquist Rate. This result has, in turn, both raised some questions concerning the interaction of autocorrelation-based estimators (e.g., Pulse-Pair algorithms) with the staggered sampled sequences and increased the complexity of the analytical models for the staggered PRT and composite filters.

A complete time-domain simulation of the staggered PRT and composite filters is currently being implemented. The simulation will include the generation of synthetic radar time series. The goals of the simulation package are: to assist in the characterization of the staggered PRT and composite filters, to aid in the development of estimation algorithms, and to provide a quasi-operational environment in which various filter architectures and estimators may be evaluated.

TABLE II-2 Scan Sequences for Pedestal Performance Verification		
PPI Sector Scan (120° Azimuth Sector)		
Tilt	Elevation Angle (deg)	Scan Rate (deg/s)
1	15	25
2	11.5	25
3	9	25
4	7	25
5	5	25
6	3	20
7	2	15
8	1	15
9	0	10
Ideal Time = 77 s Acceptable Time = 84 s		
RHI Sector Scan		
Elevation Sector = 0-30° RHI scans at 12 azimuths spaced 1.5° apart Ideal Time = 43 s Acceptable Time = 47 s		

2. Product Generation

Two new "sampling modes" were added to the product generation software. These modes extend the range of the radar system by either processing every other range gate (giving a range resolution of 224 m) or by processing every gate at near-in ranges and every other gate farther out, where azimuthal resolution is similarly degraded. These modes have not yet been used successfully because of problems in the signal processor. As a result the current maximum range of digital processing and display is about 86 km.

An algorithm to resample RHI scans was installed and tested. This algorithm takes advantage of the special geometry of the RHI scan to significantly reduce the CPU utilization below what would be required by a straightforward translation of the PPI resampling algorithm to the RHI situation.

Once the radar transmitter-antenna-receiver chain had been initially calibrated at the beginning of December, the product generation software was modified to take those calibrations into account.

the start of each tilt. Additional arguments were added to the commands from the central computer to allow that computer to directly specify the CPI length, noise threshold level, and clutter filter selection parameters directly. These parameters were previously selected automatically by the radar controller.

In addition, the digital portion of a test-target generator was designed and debugged. This unit has a synthesized Doppler offset and is controlled by the 3210 computer. The signal is injected into the receiver input so that correct Doppler processing can be validated routinely during an experiment.

The antenna control program continued to evolve as various changes were made to the mount servo control system to improve accelerations. Considerable effort went into a program to record and display the mount behavior during representative scan sequences as an aid to the mount tuning process.

The NEXRAD technical requirements (NTR) only specify the mount peak velocity and acceleration in each axis. This is inadequate for properly bounding the performance during representative LAWS scan sequences since other effects can occur (e.g., oscillations in reaching a desired position or slow deceleration) which are not bounded in the NTR.

Thus, it was necessary to establish a functional specification for mount/control software performance which was more closely aligned to our objectives. This functional specification consists of tolerable scan durations for the two scan sequences shown in Table II-2. The "ideal" values shown would be achieved by a mount which always accelerates or decelerates at $15°/s^2$ while exactly maintaining the desired scan velocities. A 10 percent longer scan duration is permitted in each case to account for practical mount deficiencies and the need to insure mount safety near the elevation lower scan limits.

Volume scans, sector scans and a series of RHI scans were successfully utilized during the quarter. However, the scan durations were longer than desired due to the combination of rate and position control. Transition to an all rate control will be achieved in the next quarter.

H. MAIN MINICOMPUTER

1. Displays and Operator Interface

The map overlay capability permitting political boundaries, air routes, etc., to be displayed along with the base products, was supplemented during October by installation of an interactive map-editing program at the test-bed, and maps of the Memphis area were obtained. The trackball software, delayed earlier by lack of a working trackball, was implemented during October. In December the provisional 'automatic zoom' of the displays was replaced by a more flexible repertoire of panning and zooming operations under control of the operator. Finally, the display and trackball software was augmented to handle RHI as well as PPI scans.

An initial facility for specifying the many parameters of a volume scan (elevation or azimuth angles, scanning speed, PRF, sampling resolution, clutter filters, etc., all potentially changing from one tilt to another), while still allowing unspecified parameters to assume default values, has been implemented.

microprocessor-based test fixture. High-level testing was also applied to several of these boards so that both the test-bed and development systems have multiple processing elements. This checkout and debug work has required the continued development of both high and low level diagnostics for the PE boards.

The availability of several working processing elements allowed a dual-PE test to be executed on the DAA. This test demonstrated the proper operation of the multiple-port memory system, with two PEs actively accessing the memory. This test was the first formal verification of the multi-processing capability of the DAA system.

In addition to checking out the PE boards, one expansion board for the multiple-port memory (MPM) was completed. The expansion board provides 3 megabytes of memory to the DAA, in addition to the 1.5 megabytes which reside on the main MPM board. Intermittent problems still appear on the original MPM board, and will require further investigation. The expansion memory board for the test-bed DAA system has not yet been tested, but is not needed for current system operation.

A number of enhancements to the DAA PE have been designed. Four of the existing seven PE boards have been modified to include these changes, and one has been tested for proper operation. The PE wire list has been modified, and a second production run of seven PE boards is currently in progress. Two new PE boards should be wired by the end of January, with an additional board being finished every 10 days after that. Several small changes to the DAA microcode definitions files have been made to handle the changes to the PE boards.

G. RADAR/ANTENNA CONTROLLER

The test-bed radar controller computer is responsible for three basic functions: real-time interpretation of commands from the test-bed central computer, dissemination of control information to the digital processing and antenna control systems, and off-line calibration and diagnosis of the radar system.

The controller has been reliably performing these basic functions for several months. All basic command interpretation and processing functions are implemented, and reliable control of the antenna pedestal has been demonstrated.

Considerable effort has been spent on the development of a system calibration data base and several calibration utilities. The calibration data base stores various system parameters (receiver gain, AGC compensation coefficients, receiver noise level, etc.) as measured by the calibration utilities. These values are then available to the real-time processing system for inclusion in the data stream. This data base has been completed and integrated into the real-time system. An integrated system calibration utility was created to allow the routine calibration operations to be performed with minimal effort, and to be automatically saved for use in later data analysis work.

Several enhancements were also made to the real-time signal processor control software for the radar controller. These changes were primarily designed to minimize the setup time lost at

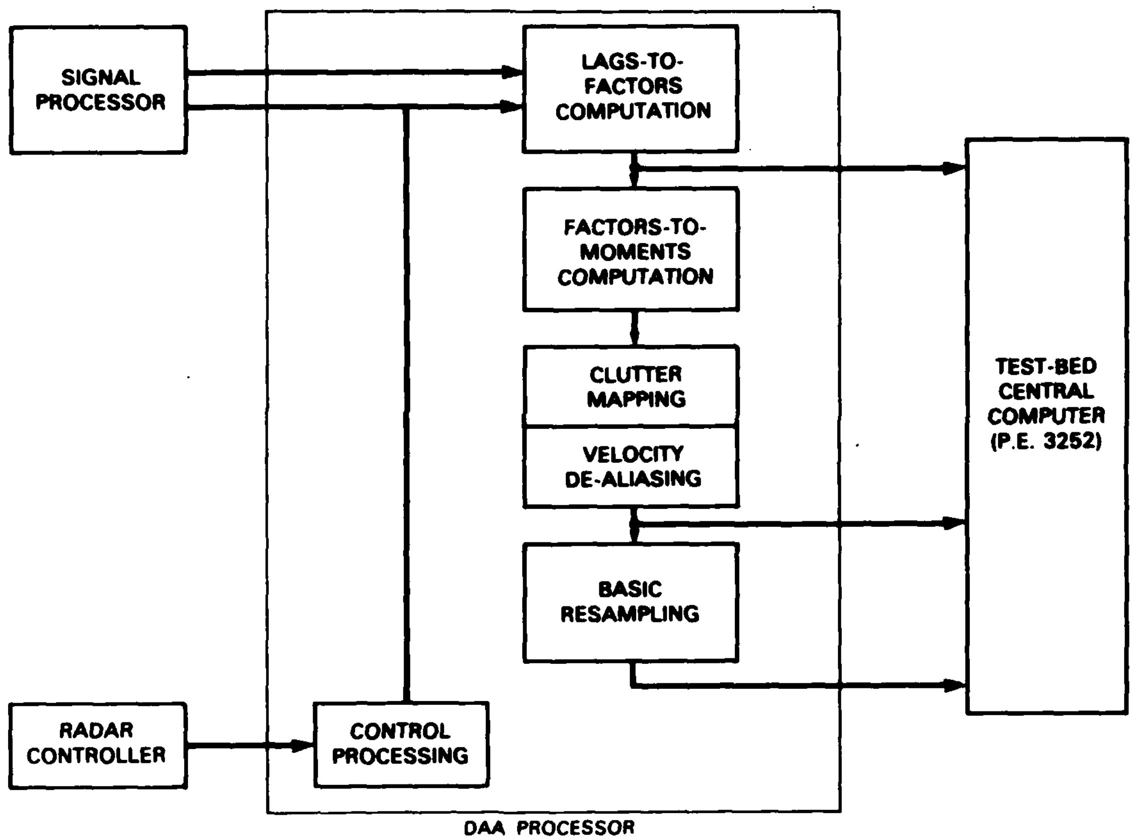

Figure II-4. DAA data flow for basic data processing.

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Software development for the DAA has been centered around the components needed to support effective data collection operations. These components include the computation of weather parameter estimates from autocorrelation measurements and the resampling of polar data to a Cartesian grid. Both of these areas have received considerable attention this quarter; initial versions will become operational in the next quarter. The specific modules involved are:

Software Module	Purpose
Lags to factors	Convert autocorrelation estimates to intermediate quantities, to be sent to the central computer for recording.
Factors to moments	Calculate final weather parameter estimates (reflectivity, velocity, spectrum width, S/N ratio).
Resampling	Resample polar tilt data to a Cartesian grid.
Control Processing	Collection and dissemination of control information, and generation of basic status display.

The data flow between these processing modules is shown in Figure II-4.

As reported in the last quarterly report, all arithmetic and data formatting routines for the lags-to-factors processing have been written and tested. These routines will be integrated with the operational software during January. This software will essentially replace the existing operational microcode. The control processing software is currently being written and will be installed along with the lags-to-factors routines. Development of the factors-to-moments software will follow.

A general-purpose message passing mechanism has been developed, which will be used as the primary method for transferring data and control information between the various processing elements. This software has been completely written, and final testing is in progress.

The design for the basic resampling module has been completed, and implementation has begun. This program will transform the radar data obtained on a spherical grid to a cartesian grid, one tilt at a time. This initial version of resampling includes several constraints, which will be removed in future enhanced versions. These constraints include: a fixed 256 × 256 cartesian output data space, fixed radar position at the center of the cartesian grid, and a cartesian resolution sufficient to insure that the maximum range radar data is included within the cartesian data space. These constraints are intended to simplify the algorithm implementation, so that a working version can be available at the start of the 1985 storm season. The time-critical portion of the resampling program has been written, and a timing analysis indicates that this version of resampling should operate in "real time" using a single processing element.

The initial production of DAA Processing Element (PE) boards (the main computational element) included a total of seven boards, two of which were debugged along with the original DAA system. In this quarter, basic testing of the five remaining boards was completed, using a

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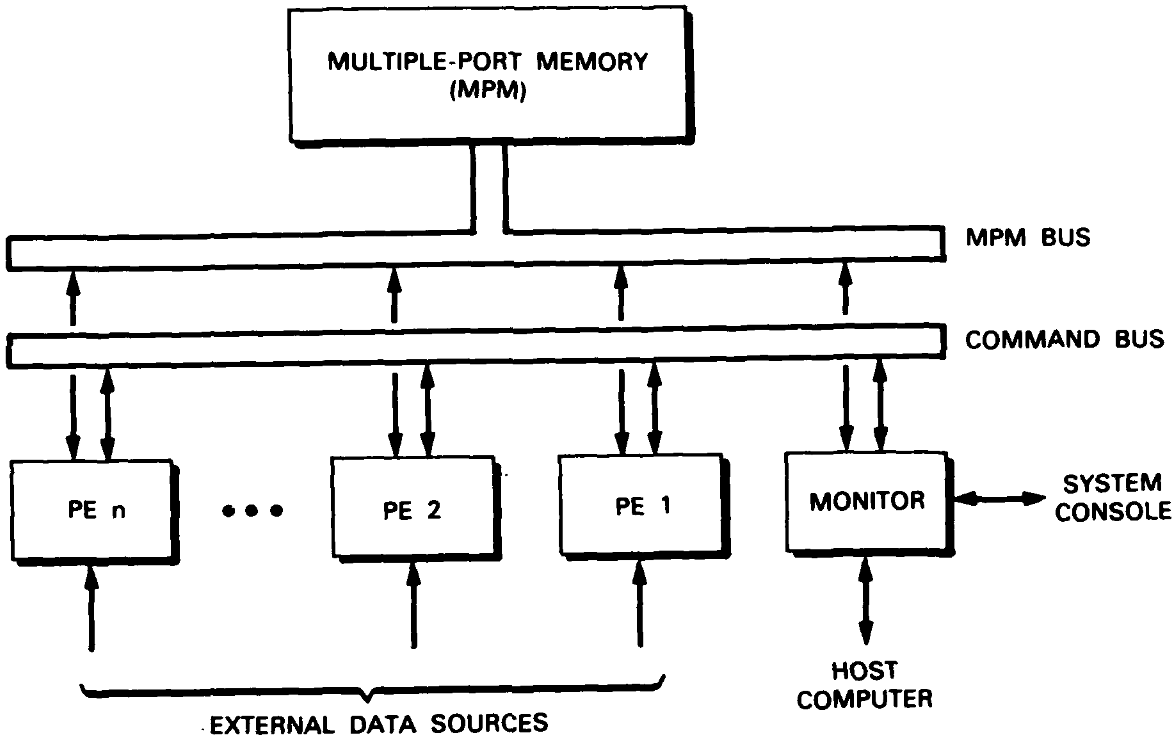

Figure II-3. DAA processor architecture.

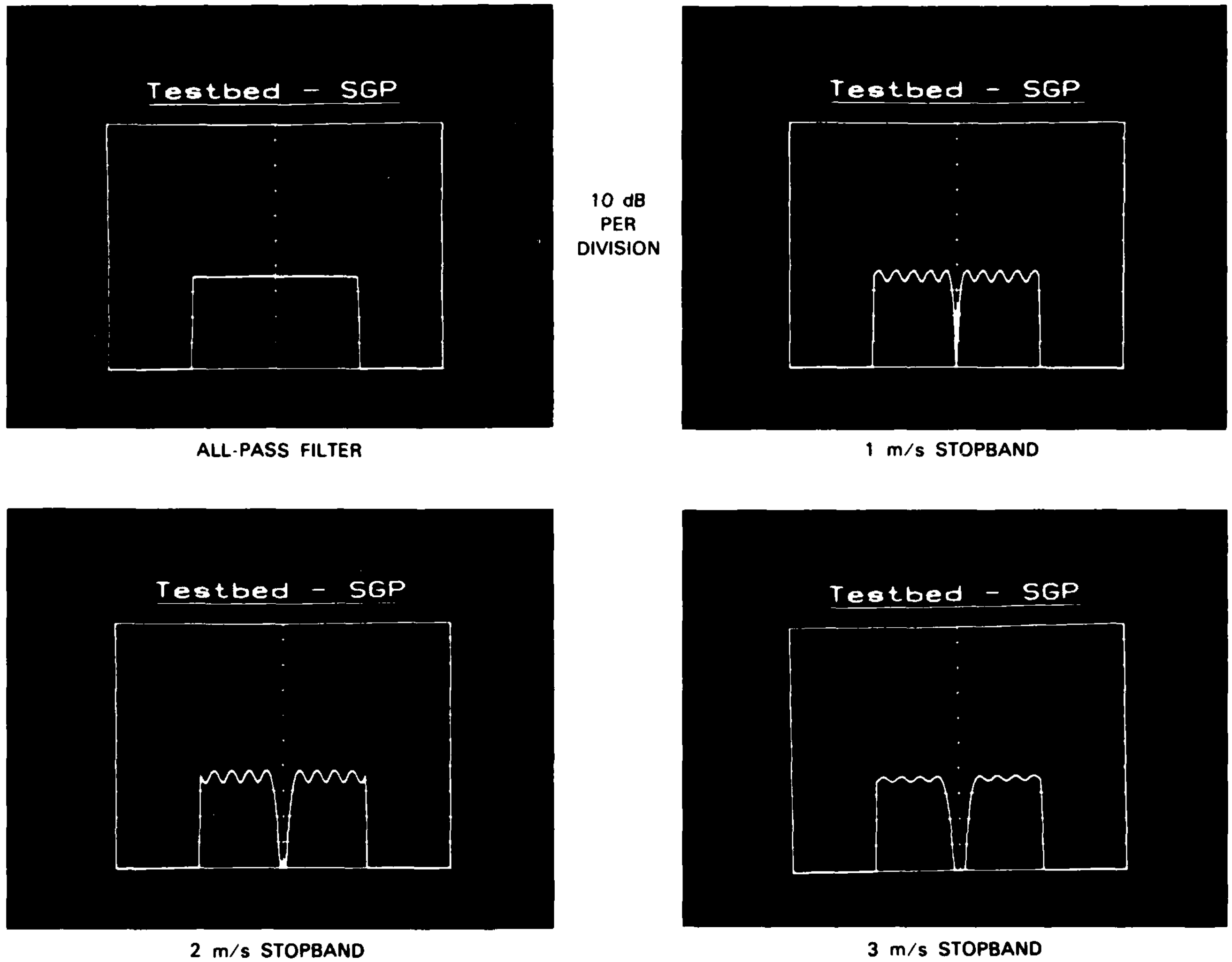

Figure II-2. Signal processor clutter filter performance on synthetic signals.

148786-R

The spectrum plots shown in Figure II-2 illustrate the operation of the clutter filter on a simulated radar input signal. This signal was input to the processor using the radar simulator unit, which supplies a digital test pattern in place of the system A/D units. The figure shows the power spectrum (derived by using a 256-point DFT) of the filtered signal, for each of four different filters. The filters shown were implemented with a 39-point impulse response and are representative of the clutter suppression capabilities to be expected from the test-bed system.

Considerable effort has gone into the development of automated calibration and diagnostic utilities for the test-bed. In particular, a calibration routine for the AGC compensation system has been implemented. This procedure determines the size of the AGC attenuation steps by examining the system response to a ramp input signal. These step sizes are then used to compensate for the attenuator action after the video signal has been sampled by the A/D units. The current calibration procedure requires various connections to be made manually and uses an external signal generator. The installation of the new test target generator will allow fully automatic AGC checkout and calibration to be performed.

Component procurement for a stripped-down version of the signal processor has been completed. This second processor will reside at the Laboratory, to be used for system diagnostics and development. Construction of the new system will begin in January.

F. DATA ACQUISITION AND ANALYSIS (DAA) PROCESSOR

The DAA processor, a Lincoln-built multiprocessor, is used to perform real-time processing of Doppler weather radar data. Figure II-3 shows a block diagram of the DAA. Two DAA processor systems currently exist — one in the weather radar test-bed for operational use, and one at the Laboratory for development.

The test-bed DAA has been basically working for some time, but minor interface problems are still being uncovered. Simple hardware and software changes have been necessary to allow the DAA to reliably obtain autocorrelation information from the signal processor. The test-bed DAA system is now capable of operationally transferring the signal processor outputs to the central test-bed computer (P.E. 3252) for recording and display.

A variety of off-line programs have been written for the DAA to assist in the checkout and calibration of the radar and signal processor. These programs allow the user to obtain unprocessed autocorrelation or (single gate) time series data from the signal processor, for viewing or recording on the P.E. 3252 computer. A basic spectral plotting utility (SGP) is available for generating a time-varying plot of the power spectrum of the received signal; a noise/bias plot program is also available.

6. Additional Clutter Data

There is an urgent need for representative TDR clutter data for use in determining TDR siting strategies and clutter suppression approaches for both the TDR and/or NEXRAD when used to detect LAWS. Measurements at a variety of on- and off-airport sites are required. However, it now appears that the test-bed radar will typically visit only a single site per year. To significantly increase the available clutter data base, arrangements were made with the Lincoln Air Vehicle Survivability Evaluation (AVSE) program to use their Phase 0 X-band clutter measurement system for measurements of opportunity at Dallas-Ft. Worth Airport, Eglin Air Force Base/Ft. Walton Beach, Florida, Memphis Airport and the Olive Branch, Mississippi test site.

During the quarter, measurements were carried out at:

(a) Eglin AFB/Ft. Walton Beach, Florida on 15 November 1984 at the site shown in Figure III-2

(b) Memphis International Airport, Tennessee on 19 November 1984 at the site shown in Figure III-3, and

(c) the Olive Branch, Mississippi test site on 19 November 1984.

Antenna phase center heights of 25 ft and 50 ft were used at the airports. At the test site, the principal objective was to compare the test-bed S-band clutter levels with the AVSE X-band levels, so only a phase center height of 25 ft was used. Maps showing the regions where the clutter scattering cross section exceeded -40 dB at each of these sites are given in Section F of the following chapter on Experimental Data Reduction.

FORT WALTON BEACH QUADRANGLE
FLORIDA – OKALOOSA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

FLORIDA

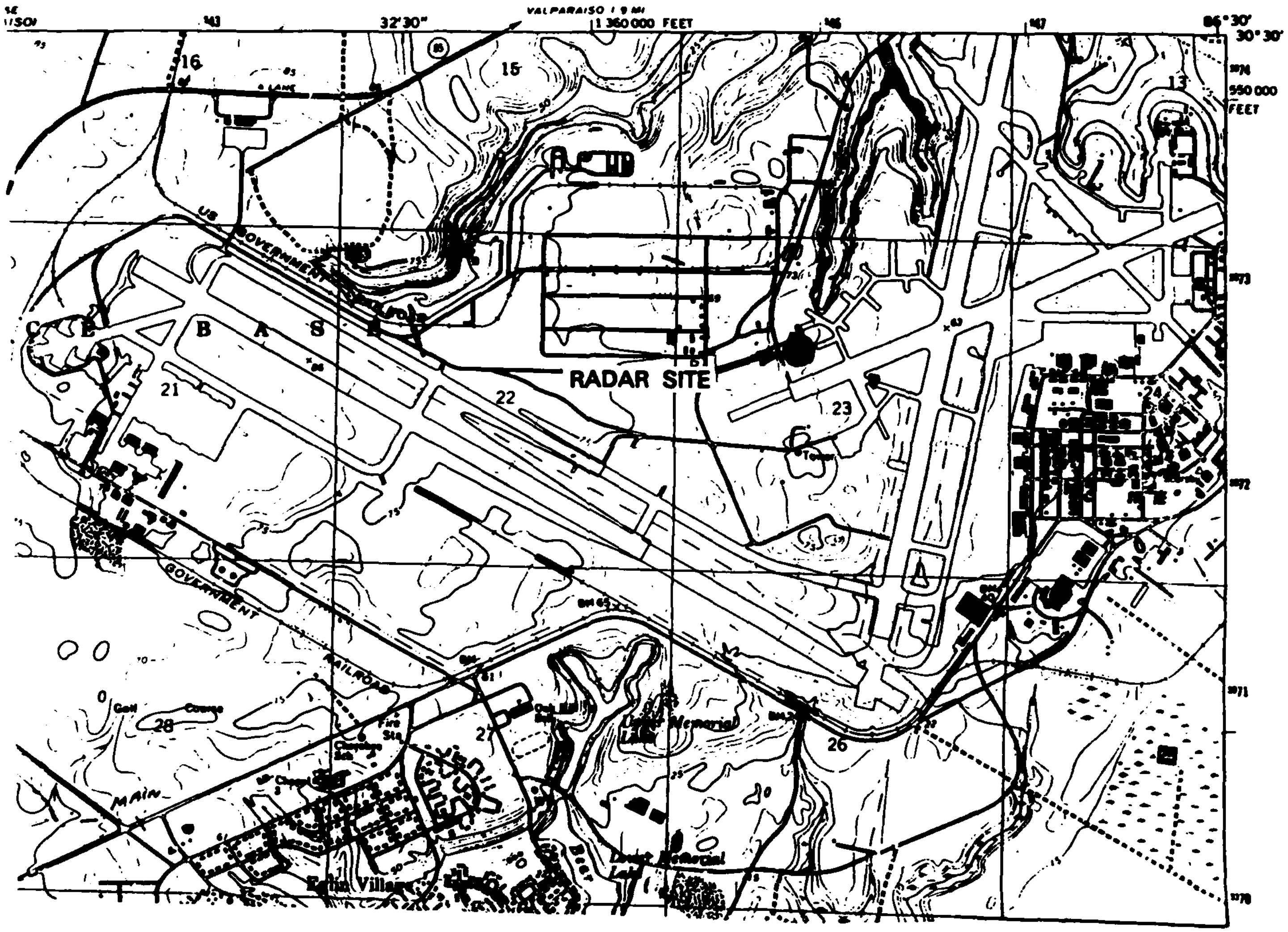

Figure III-2. Clutter measurement site at Eglin AFB/Ft. Walton Beach, Florida.

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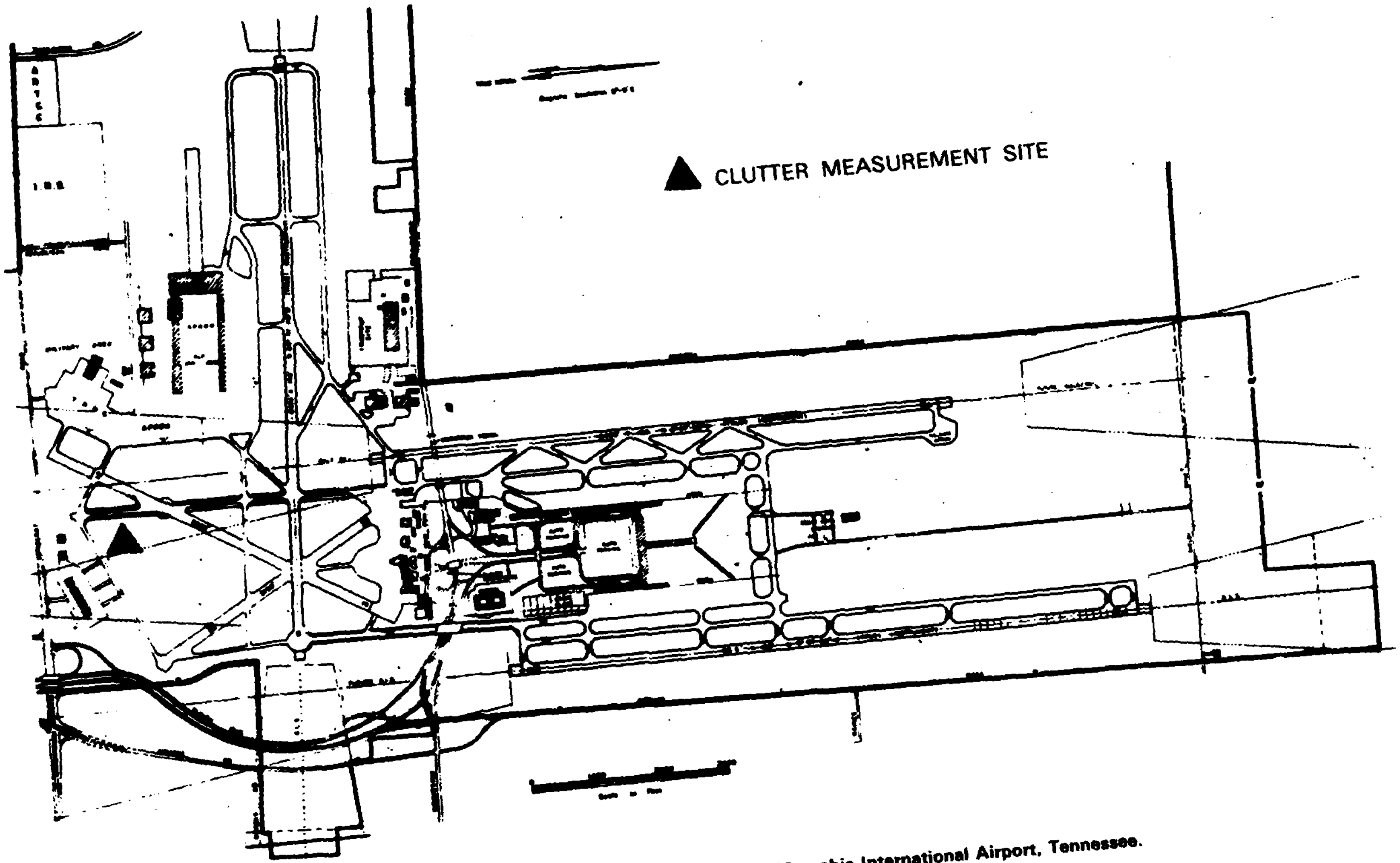

Figure III-3. Clutter measurement site at Memphis International Airport, Tennessee.

IV. EXPERIMENTAL DATA REDUCTION AND ALGORITHM DEVELOPMENT

A. PERKIN-ELMER COMPUTER SYSTEMS

Figure IV-1 shows the data analysis facility computer systems. The second of two Perkin-Elmer P.E. 3242 computers has been installed, and is in operation at partial capacity using the latest version of the operating system (OS 7.2), 8 megabytes of memory, and 474 megabytes of disk storage. Full capacity operation is dependent upon final installation of the 300 megabyte disk drive removed from the project's original P.E. 3242.

Two Fujitsu Eagle 474 megabyte Winchester-type disk drives have been installed, one on each P.E. 3242 computer. Some difficulty was encountered coordinating the installation of the Spectra Logics controller boards and the proper formatting of the disks. The new disks provide a significant increase in storage capacity, as well as the potential for increased throughput of data due to their comparatively rapid read and write capabilities.

Due to repeated system crashes of our original P.E. 3242 during October and November, and the apparent inability of the local Perkin-Elmer office to solve the problem, Perkin-Elmer was officially notified (via the Lincoln Purchasing office) of our problem and lack of satisfactory maintenance response. Perkin-Elmer resources from their New Jersey office were subsequently applied to the problem, with little more in the way of results. Currently the faulty CPU is operating satisfactorily with two megabytes of Perkin-Elmer memory, as compared to the 8 megabytes of Associated Computer Services memory which was installed some months ago. In an effort to encourage finding a solution to our problem, P.E. was offered full time access to the faulty CPU, once our second P.E. 3242 is fully operational and is able to temporarily handle all users.

Our installation of OS 7.2 will be validated on the new P.E. 3242, and will subsequently be installed on the original P.E. 3242, once there is confidence that that system is operating correctly.

B. RADAR DATA ANALYSIS SOFTWARE DEVELOPMENT

This quarter saw a major enhancement to the Common Radar Data Format (CFT) read and write software packages to allow arbitrary limiting and scaling of product data. Also, a number of useful routines were added for storing and retrieving various types of product-related information. These changes were almost entirely transparent to existing programs; however, a number of programs may be modified to take advantage of these enhancements.

The CFT derived field utility received attention this quarter. The intention is to have available a general software "template" which will greatly facilitate the generation of specific programs for deriving new data fields in radar coordinates. The first of these, a program for deriving radial shear fields, is expected to be available in mid-January.

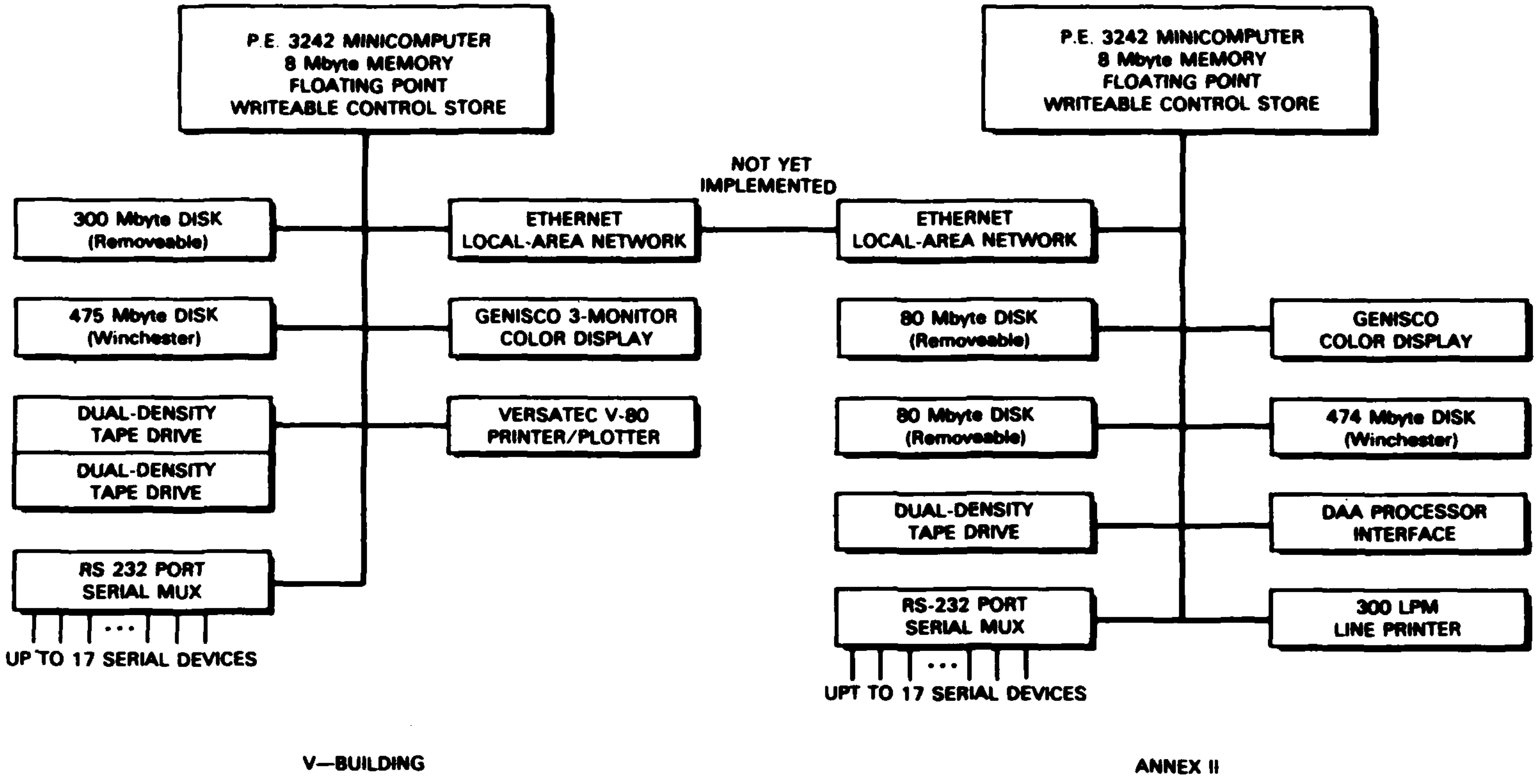

Figure IV-1. Block diagram of data analysis facility.

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The NSSL Universal to CFT translator was written. One difficulty involved in this particular translator was the fact that in the NSSL format no scan limits are specified. Therefore, a utility program for recording the start and end of scans had to be written. Furthermore, this program had to also record tape changes, to facilitate batch processing of data. An effort is underway to consolidate all existing Universal translators into a single package.

The RESAMP program, designed to resample radar coordinates into cartesian format (CAR), underwent some improvements. Significant among these is the clipping of radials in range so that only pertinent range gates are processed; this yields a large reduction in computation time when partial or offset fields are being resampled. Also, command interfaces have been written, and code is being prepared, for the inclusion of signal-to-noise thresholding of products.

A specification was established for a Cartesian Exchange Format (CEF). This is intended as a simplified cartesian data format to allow parties outside Lincoln access to certain CAR data created by the Lincoln data reduction software. The next stage in this effort is a translator from CAR to CEF, and the production of sample data.

The program CARLOOK is now available to facilitate the interactive examination of data values and header information contained in any CAR format data file.

C. MESONET DATA ANALYSIS

October was largely spent designing the overall software development and data analysis plan for the mesonet project; a project memo was issued. A software package to analyze and process mesonet and LLWSAS data is currently being implemented. This is a significant effort involving the development of many different programs. The data from both the mesonet (up to 30 stations) and the Low-Level Wind-Shear Alert System (LLWSAS, 6 stations, winds only) will be translated into our Common Instrument Data Format (CIDF), and all subsequent programs will access the data in CIDF. This philosophy allows us to confine the input format for analysis programs to CIDF, and thus to be able to accept data in any new format with little extra effort.

During this last quarter of 1984, the complete mesonet data set was translated into CIDF. A translator was also written to convert LLWSAS data into CIDF. Instead of simply reformatting the 8-s wind values, the 1-min. average wind speed and direction and the 1-min. peak wind speed are computed and written out. This will allow us to use the LLWSAS data exactly as we do the mesonet wind data without a lot of special computations built into the data listing and display programs. The 8-s values can always be retrieved in a separate translation.

A preliminary analysis of the data (in CIDF) must be performed before the final calibration constants can be determined. The analysis will focus mainly on compensating the wind speed measurements for site obstructions and correcting the wind direction. The pressure, relative humidity, peak wind speed, and temperature will all be checked for bad values. They will be corrected or edited. Once the calibration constants and bad values have been determined, the final translation can take place.

A number of programs were written this quarter that will be used for the compensation of site obstructions: a plotting program for any mesonet calibration variables that are a function of azimuth, a "histogram" program to compute the number of one-minute averaged wind speed values that fall within each degree of azimuth for each station for one day and the overall average wind speed as a function of azimuth for that day, a program to merge as many of these one-day histogram outputs as desired to build, for example, a monthly or seasonal average histogram, a smoothing program that smooths data using a cosine weighting function of user-specified width, and a program to compute each station's "transmission factors" based on the ratio of the smoothed average wind speed values to the smoothed unobstructed mean wind speed values, as a function of azimuth.

Upon examining the mesonet data it was found that certain sensors at certain stations were reporting "bad" data. A CIDF editor was written to find the times, according to an algorithm, at which a particular sensor is recording erroneous values. This software, for example, will be used to eliminate the peak wind speed "chatter" that occurred at a couple of the stations during light wind conditions, and the contaminated average wind speed data for those same times. This editing must be accomplished before the wind speed calibration factors (based on the site obstructions) can be determined. This "editor", which allows specification of the sensor, the time period, and the platform that is to be "checked", can also be used to detect any event such as a microburst that can be described by an algorithm. The output of this program is simply a list of times at which the conditions of the algorithm are met. When this is used for editing, the information is compiled into a data base which is then used by another program to delete the erroneous data. The complete editor and the compiler to create this data base were designed and coded this quarter, and an algorithm to reject peak wind speed chatter has been validated.

During December, time was spent designing and coding a "final" translator which reads in a CIDF file of mesonet and/or LLWSAS data and allows the user to turn data "bad" (missing) according to the above-mentioned data base, to calibrate the data and/or to compute derived products such as corrected relative humidity, dew point and net rainfall using edited and/or calibrated values.

After the data has been finally translated, an inventory will be taken to determine the overall success of our data collection effort and to provide an index of the total available data for each day. At this point the data will be run through a program that searches for wind shear. The algorithm that we will be using was proposed by Dr. Ted Fujita to detect microbursts but can be easily modified to search for gust fronts as well. When any wind-shear event is found in the data for a particular station, a time series plot will be generated for each of the recorded variables. Examination of these plots can help determine if a true wind-shear event has been identified.

Further confirmation of the detected wind-shear events can be obtained from synoptic plots over the entire network of wind vectors (this can include the LLWSAS stations), temperatures, dew points, and pressures. These plots require a base map on which the data is plotted at the exact location of the appropriate station. Eventually, these plots will be superimposed with Doppler radar data for comparison.

Once the microburst (and gust front) events have been identified and confirmed, statistics about those events can be calculated. Of particular interest are the frequency of peak wind values, the direction of the peak winds, the pressure, temperature, and dew-point changes during these wind-shear events, the overall duration of the (half-peak) winds and the diurnal distribution of microbursts and gust fronts. Graphs of these various statistics will be produced.

There is a great curiosity to know whether or not we have any hazardous wind shear recorded in our mesonet data before we go through the long procedure of calibrating and correcting the data. To find out, we wrote a very simple program to print out peak wind speed values greater than 10 m/s along with the times the peak winds were recorded. Each day was run separately, and statistics were hand-compiled based on the daily data. A brief report on what was found will be forthcoming in the next quarter.

A preliminary analysis was carried out by M. Wolfson for a microburst which induced a 30.2 m/s (68 mph) peak wind at mesonet station #25 at 1806 CST on 20 October 1984. Before the onset of the microburst, the environmental wind was 7 to 9 m/s (16 to 20 mph) from the southerly direction. In 2 min., the wind reached its peak, followed by a decrease to below 15 m/s (34 mph) in the next two minutes. The duration of this microburst, defined as the period of one-half of the peak wind speed, was 4 min. (Figure IV-2).

A detailed analysis of the mesonet data revealed that the microburst was located just behind a gust front which swept across the Memphis area. Consequently, the area of the microburst, after its dissipation, was replaced by the cold air pushing behind the gust front. Both temperature and pressure changes were characterized by those of a gust front except for a significant pressure drop during the microburst winds.

This microburst was accompanied by a very strong wind shear at low altitude. A hypothetical aircraft penetrating the storm from southeast to northwest would experience a 20 m/s (39 knots) increase in headwind, followed by a 15 m/s (29 knots) loss of headwind within approximately 3 km (10,000 ft).

D. LOW-ALTITUDE WIND-SHEAR ALGORITHM DEVELOPMENT

The low-altitude wind-shear (LAWS) detection algorithm development effort is aimed at producing an automatic procedure for recognizing hazardous wind-shear events from Doppler weather radar measurements. The current focus of the algorithm development is a very simple technique for real-time testing during the 1985 test-bed experimental program. This preliminary algorithm will attempt to identify LAWS hazards (primarily microbursts) using a straightforward composition of simple feature fields, e.g., radial shear, reflectivity gradients, etc.). Some basic image processing techniques (such as spatial filtering) may be used in the generation of the feature fields.

The overall design for the algorithm development task has been worked out, and a development plan will soon be distributed in memo form. The various software development and data preparation tasks have been identified, and implementation of these took place this quarter.

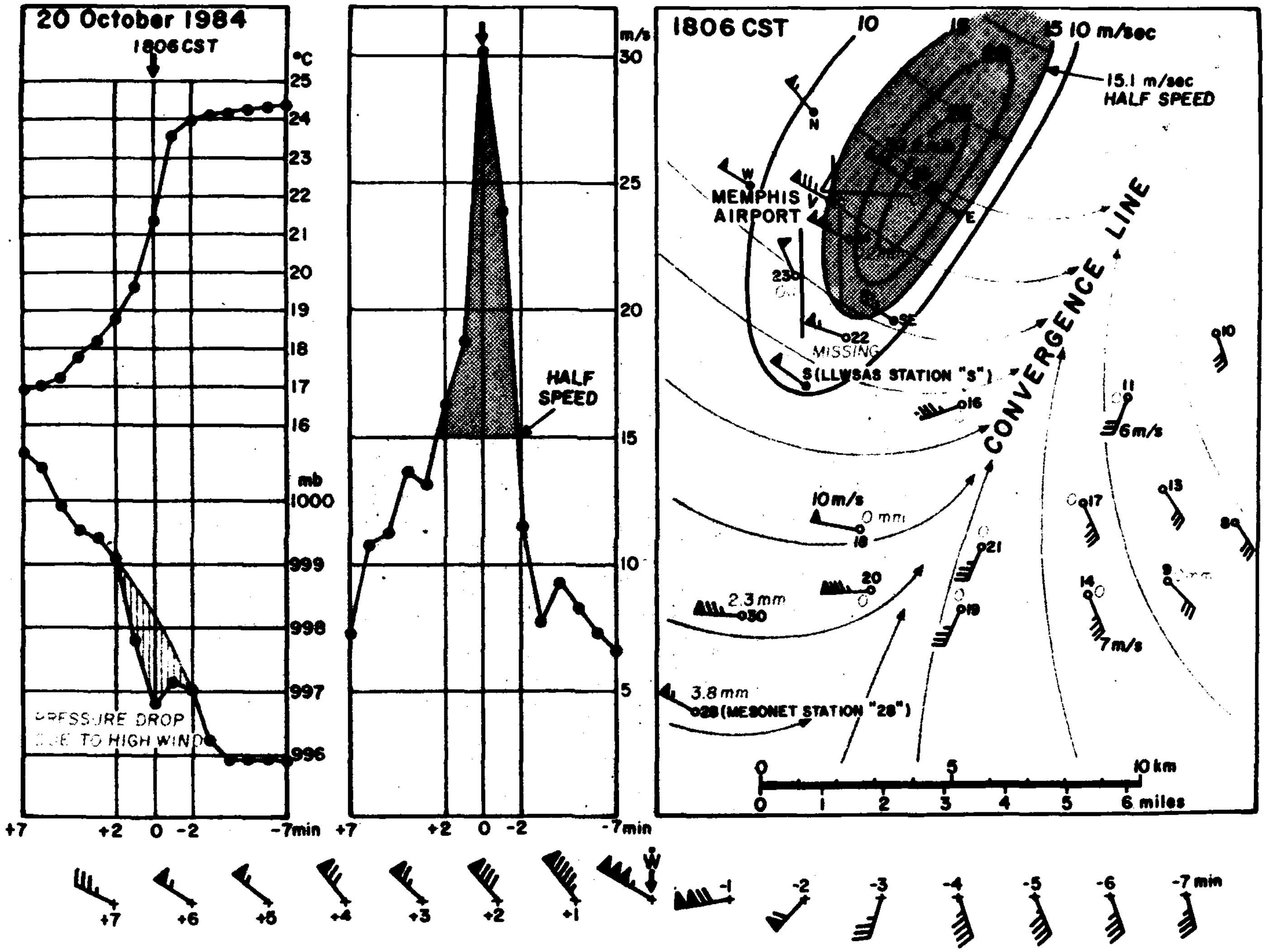

Figure IV-2. Microburst on 20 October 1984 at Memphis Airport.

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A program to "composite" any number of 2-dimensional feature fields with arbitrary weighting was completed, and reviewed. The composite feature field will ultimately be our best determination of "hazards" and will be compared with "truth" to score our detections.

A program to map a data field to an output feature field of integer values from 0 to 100 has been designed and implemented. The thresholding table to perform the conversion from real data to the integer "feature" field is user-specified in terms of an arbitrary number of linear segments (probably would not exceed 20). The integer (dimensionless) feature field will be easy to combine with other feature fields to produce the composite hazards field.

The data sets that will be used to test the algorithm have been decided upon and requested from the National Center for Atmospheric Research. These data sets all have the common properties of having had a "true" 3-dimensional wind field derived for a portion of the space that they cover, of having the spectrum width field recovered for them (after much effort), and of having edited velocity fields (de-aliased and clutter removed by hand) which were used as input to the wind derivation algorithm.

All of our work will be done with data in our "CAR" format, and work was completed this quarter on translating the wind fields that will be provided to us by NCAR into this format. A program to "scan" or examine each bin in a CAR layer is required both for testing the programs currently under development and for determining the location of the "true" wind-shear hazards based on the derived 3-dimensional wind fields.

A basic utility for entering regions of hazard (and the hazard level) was designed and coded, but not completely tested by the end of the quarter. This will be used to enter the "truth", i.e., the region surrounding the hazardous area of a given wind field. Multiple hazard levels and/or regions can be entered in this way.

The design has begun for the program which will compute radial, azimuthal, and "total" shear from the Doppler velocity field. A template program to compute any derived field based on radial input that has already been developed as a CFT utility will be used extensively.

Many of the preliminary programs for handling the Cartesian radar data and feature fields were completed by the end of December and placed in the "LAWS" account on Perkin-Elmer. This nearly ends the first phase of our software development effort which has been focusing on developing tools to handle, combine, display, and create Cartesian data files. The next phase of our efforts will be devoted to computing features from the radar data (in both radial and Cartesian format) and to effectively score our detections based on the true hazards present.

Alice Brown (a Harvard undergraduate) finished her project memo entitled "An Investigation of Three Smoothing Methods for Weather Radar Data." This memo is a summary of the work she performed last summer. Diana Klingle (a Purdue PhD candidate) worked at Lincoln the week before Christmas on her ATC project report entitled "A Gust Front Case Studies Handbook." The reported work was accomplished over a period of 8 months (September 1983 — May 1984) at the National Severe Storms Laboratory in Norman, Oklahoma. The report was completed and sent to Publications this quarter.

E. TURBULENCE ALGORITHM DEVELOPMENT

Turbulence algorithm performance in the context of the anticipated CWP product format will commence with initial emphasis on establishing the integrity of the UND airborne turbulence data from 1983.

F. CLUTTER ENVIRONMENT ASSESSMENT

Preliminary reduction of the Eglin AFB/Ft. Walton Beach, Memphis International Airport and Olive Branch clutter measurement data was accomplished by the AVSE program staff. Figures IV-3 to IV-5 show the regions where the clutter scattering cross section (σ_0) exceeds –40 dB. In the next quarter, we will develop software to:

1. convert the σ_0 levels to effective dBz levels, and
2. display the effective clutter levels taking into account suppression by clutter filters and/or clutter maps.

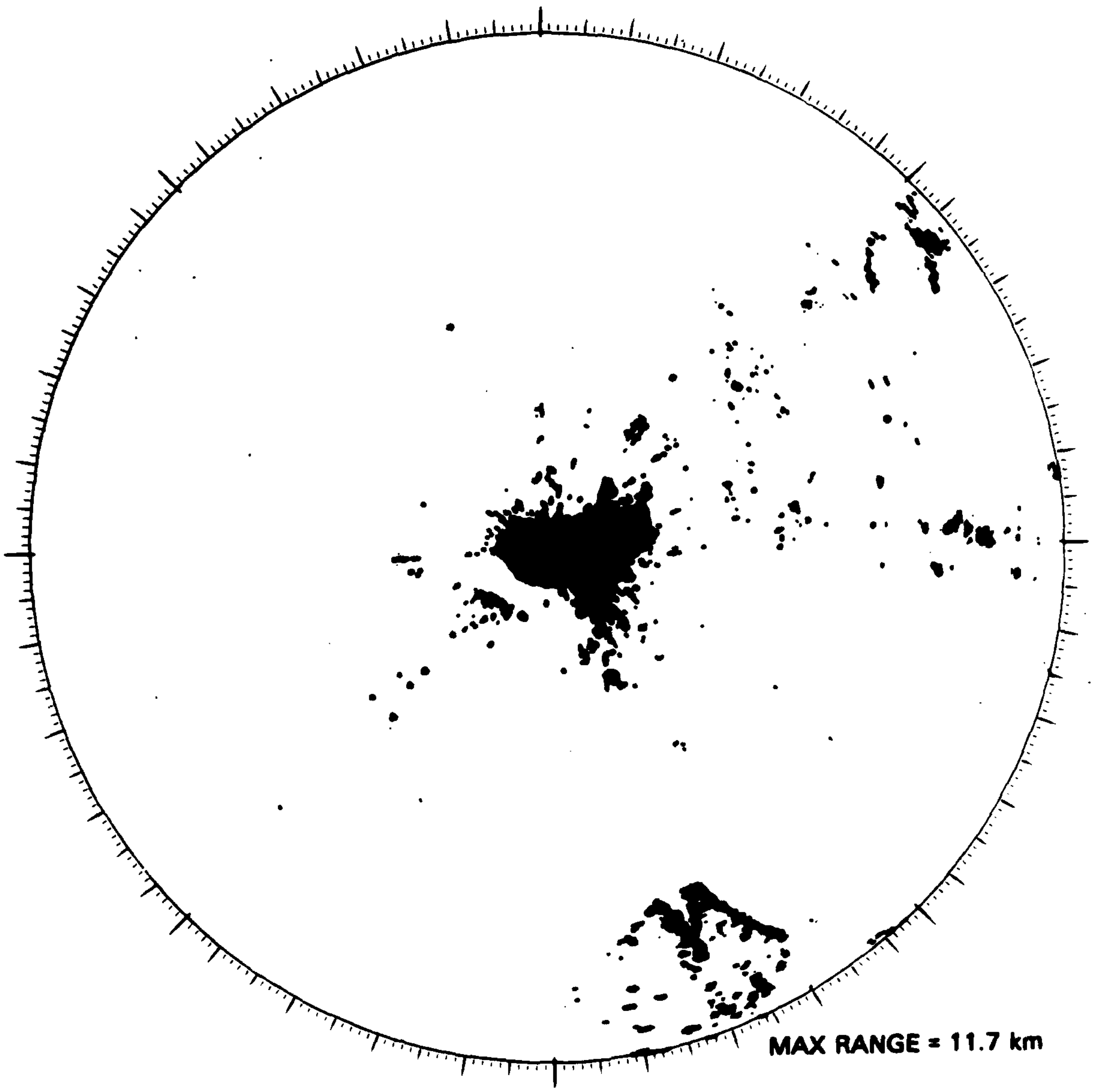

Figure IV-3. Clutter at Elgin AFB/Ft. Walton Beach, Florida site with scattering cross section greater than -40 dB.

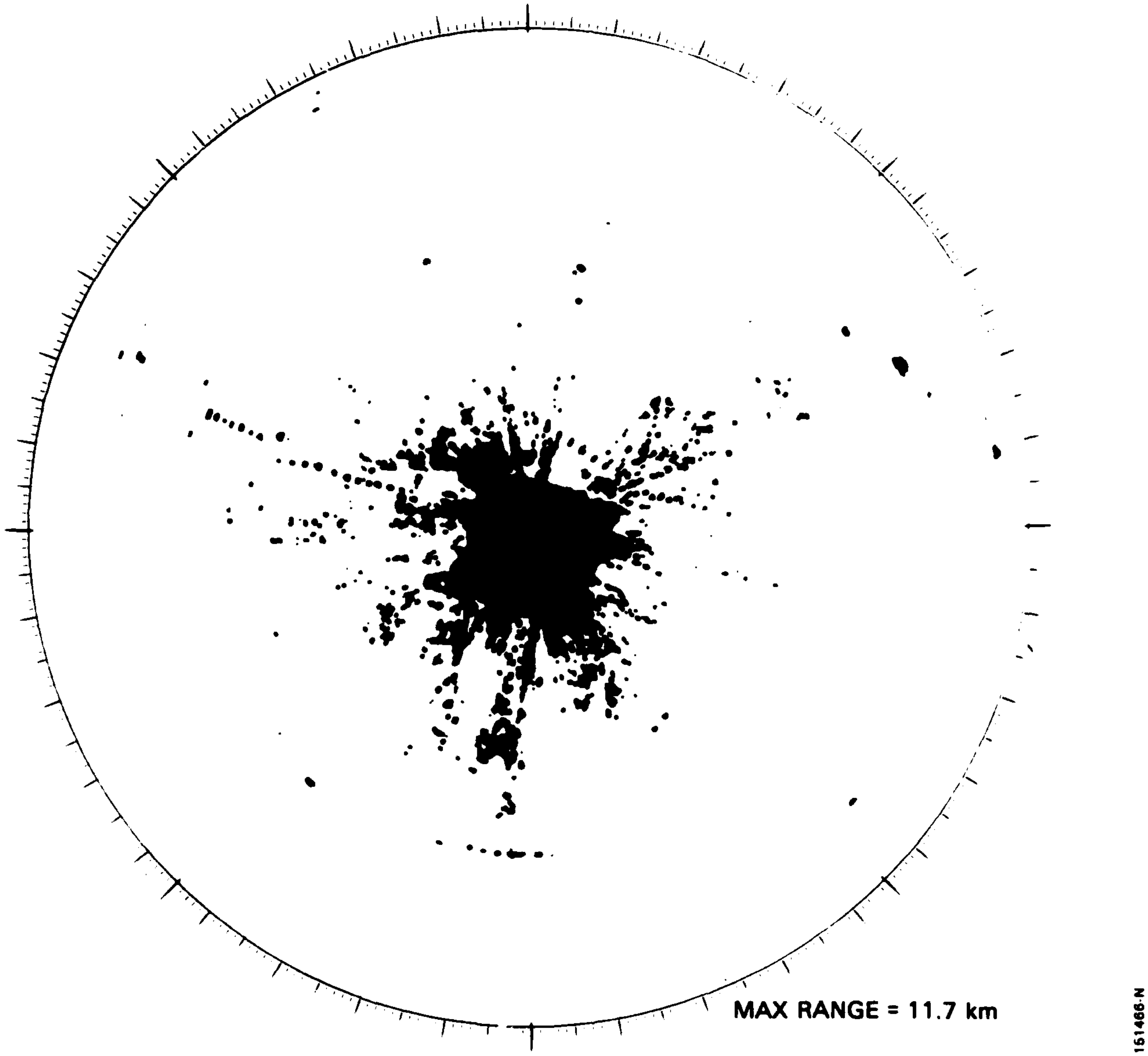

Figure IV-4. Clutter at Memphis International Airport site with scattering cross section greater than -40 dB.

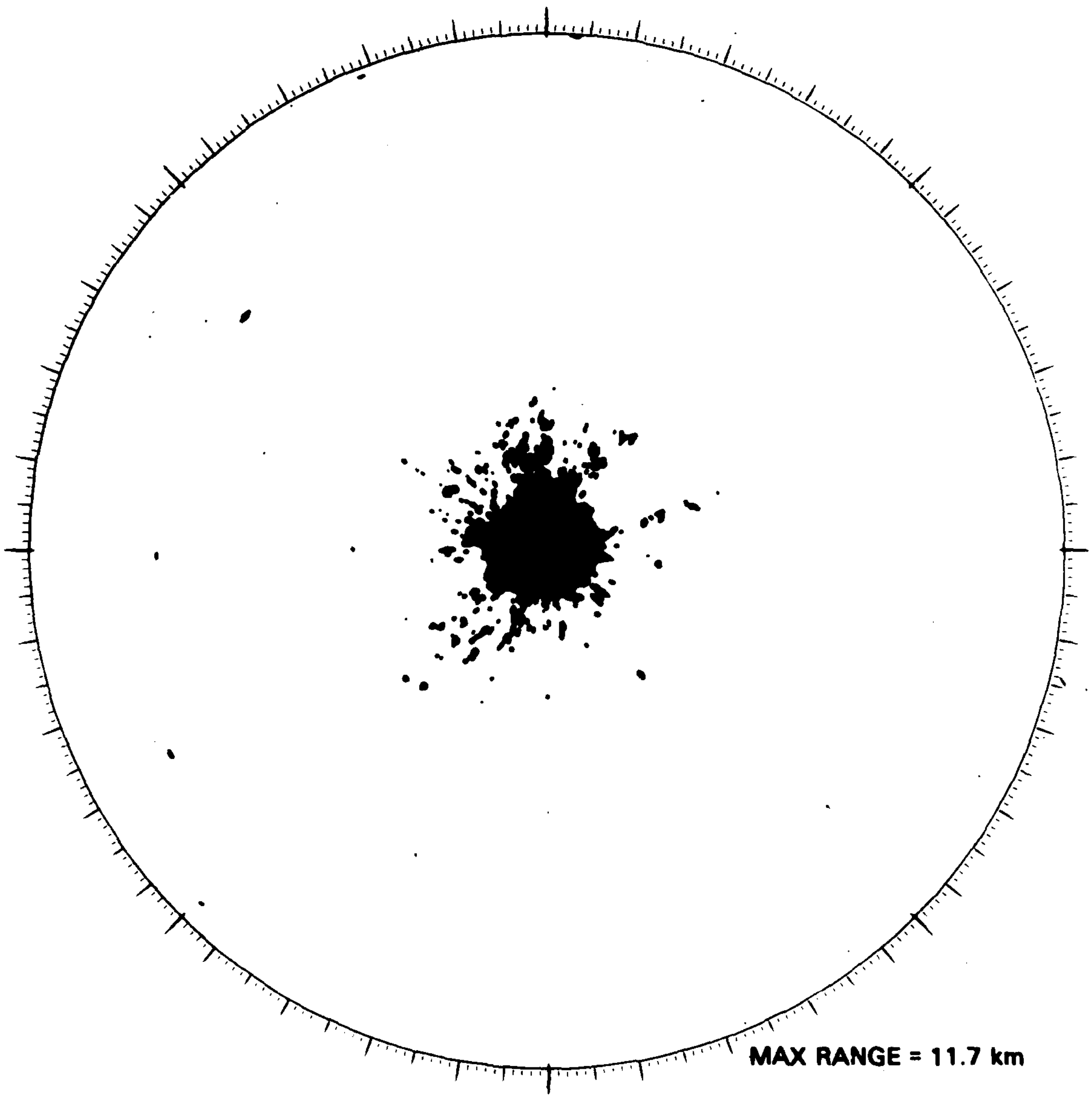

Figure IV-5. Clutter at Olive Branch, Mississippi test site with scattering cross section greater than -40 dB.

V. ASSESSMENT OF UTILITY OF NEXRAD PRODUCTS FOR ATC USE

As an outgrowth of the Boston Area NEXRAD Demonstration (BAND) analysis, Lincoln has been tasked by the FAA to develop a vertical cross section product for arbitrary user-supplied end points. Work will commence in detail on an algorithm to generate this product next quarter.

Planning continued for a product demonstration at the Memphis ARTCC in September-November 1985. A specification for the high-resolution color display/work station to be used at the CWSU was prepared and is undergoing Air Force review. We plan to make a vendor selection by the end of February.

Lincoln personnel made a presentation on weather product issues to representatives of the Sector Suite/Advanced Automation System Program in October.

VI. SPECIFICATION OF NEXRAD PRODUCTS FOR THE CENTRAL WEATHER PROCESSOR (CWP)

A. LAYERING ALGORITHM DEVELOPMENT

The functional specification for the NEXRAD layer composite reflectivity and turbulence algorithms developed jointly by Lincoln personnel and NEXRAD JSPO representatives has apparently proved successful in that no further inquiries from the NEXRAD JSPO have been received.

One known difficulty with the turbulence-layered product is that the NEXRAD-specified spectrum width accuracy may not be adequate to estimate the kinetic dissipation rate accurately near the radar. It is unclear how issues such as this will be addressed in the context of the current NEXRAD specification and algorithms.

B. TRACKING AND PREDICTION

A prototype binary correlation tracker was implemented. This tracker generates displacement vectors on the basis of spatial correlations of thresholded reflectivity maps generated from consecutive volume scans. Preliminary comparisons against the basic correlation track (documented in Lincoln Project Report ATC-124) indicate good agreement of the displacement vectors for regions in-track by both trackers. The binary correlator is expected to require less execution time than the basic correlator as many of the arithmetic computations in the latter are reduced to logical comparisons in the former.

Timing estimates for the basic correlation tracker, more detailed than those appearing in ATC-124, are currently being generated to isolate the portions of the tracking algorithm which are the most computationally intensive. Similar estimates are to be generated for the binary correlator as well.

Evaluations are underway to ascertain which of the routinely generated (i.e., per volume scan) NEXRAD products (N-Products) will be best suited as input data for the trackers. This is important because the spatial quantizations of the Cartesian data processed by the ATC-124 basic correlation tracker did not correspond precisely to those of the current, analogous, N-products.

A related set of evaluations is being performed to determine which of the routinely generated N-Products will be best suited as a basis for the creation of the extrapolated reflectivity maps. The current algorithm consists of the displacement of fixed-level contours through the association of correlation track vectors with the contours' centroids. Candidate N-Products for this application are Composite Reflectivity, Layer Composite Reflectivity, and Composite Reflectivity Contour.

PRINCIPAL CONTRIBUTORS

The principal contributors to this report were M. Wolfson, M. Merritt, W. Drury, M. Goldburg, P. LaFollette, and J. DiStefano.

GLOSSARY

A/D	Analog-to-Digital
AGC	Automated Gain Control
AGL	Above ground level
APU	Auxiliary Processing Unit
ARTCC	Air Route Traffic Control Center
AVSE	Air Vehicle Survivability Evaluation
BAND	Boston Area NEXRAD Demonstration
CAR	Cartesian Format
CEF	Cartesian Exchange Format
CFT	Common Radar Data Format
CIDF	Lincoln Laboratory Common Instrument Data Format
CPI	Coherent Pulse Interval
CPU	Central Processing Unit
CWP	Central Weather Processor
CWSU	Center Weather Service Unit
DAA	Data Acquisition and Analysis (Processor)
dBz	Unit of weather reflectivity
DCP	Data Collection Platform (implies transmitter to GOES satellite)
DFT	Discrete Fourier Transform
FAA	Federal Aviation Administration
FAATC	Federal Aviation Administration Technical Center
FIR	Finite Impulse Response
GOES	Geostationary Operational Experimental Satellite
IIR	Infinite Impulse Response
IOTF	Interim Operational Test Facility
JAWS	Joint Airport Weather Studies
JDOP	Joint Doppler Operational Program
JSPO	Joint System Program Office (for NEXRAD program)
LAWS	Low-Altitude Wind Shear
LLWSAS	Low-Level Wind-Shear Alert System
mesonet	Refers to a network of automatic weather stations with a close spacing, i.e., a "mesoscale" spacing. Lincoln's spacing might be called "microscale."

MPM	Multiple-Port Memory
NCAR	National Center for Atmospheric Research, Boulder, Colorado
NEXRAD	Next Generation Weather Radar
NIMROD	Northern Illinois Meteorological Research on Downbursts
NSSL	National Severe Storms Laboratory, Norman, Oklahoma
NTR	NEXRAD Technical Requirements
P.E.	Perkin-Elmer
PE	Processing Element
PPI	Planned Position Indicator
PRF	Pulse Repetition Frequency
PROFS	Prototype Regional Forecasting Sytem
PRT	Pulse Repetition Time
RFI	Request for Information
RHI	Radial Height Indicator
RRWDS	Radar Remote Weather Display System
SGP	Signal Gate Processing
S/N	Signal-to-Noise
TDR	Terminal Doppler Weather Radar
TMF	Transportable Measurement Facility
UND	University of North Dakota
VSWR	Voltage Standing-Wave Ratio

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